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GUIDELINES FOR THE COMPARISON OF HUMAN AND HUMAN ANALOGUE BIOMECHANICAL DATA

Second Annual Report of an Ad-Hoc Committee

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REVIEW

The first annual report of this Ad Hoc Committee was presented December 6, 1974 (1). This established the effort to develop guidelines to ensure precise comparison of mechanical data from diverses studies of impact events on human subjects and human analogues as the central purpose of the committee. Furthermore, it became obvious that this should be a continuing effort.

Five specific guidelines were presented. They can be summarized as requiring use of (1) right hand orthogonal coordinate systems to define: (2) a laboratory coordinate system, (3) anatomical coordinate systems, (4) instrumentation coordinate systems and (5) initial values of all coordinate systems for any set of experiments or observations. Several examples of anatomical coordinate systems were given. In particular, orthogonal three dimensional coordinate systems were defined and illustrated for the human head and the first thoracic vertebral body. References for the use of these coordinate systems for investigation of human and human analogue dynamic response were given. The ad hoc committee has adopted the five guidelines and the head and first thoracic vertebral body anatomical coordinate sytems as previously defined and recommends their use to the community of interest in biomechanics (1).

BACK GROUND

The guidelines specifying use of coordinate systems based on the anatomy and the instrumentation require continuing effort. As an aid to visualizing these coordinate systems selection of the origin and the first, second, and third axes of any coordinate system within or on the anatomy will have some approximate relation to the anterior-posterior, lateral, and superior-inferior directions of the experimental subject. In order to specify such directions a standard anatomical position will be described. Each anatomical segment will be positioned according to the standard position. The description of the standard anatomical position is Guideline 6.

Selected definitions of anatomical coordinate systems which are practical to measure in the anatomy of living humans and in the structure of analogues used in lieu of living humans will be proposed. Also, the need for certain classes of instrumentation coordinate systems which prove more practical for certain types of testing, for example, optimum instrumentation placement on

living subjects and anthropomorphic dummies has been considered. For any defined coordinate system it has been the policy of the committee to review the use of the coordinate system definition as described in the literature or technical reports before adopting it. Any number of candidate coordinate systems could be defined but only a limited few are likely to prove useful. For this report the effort to propose useful coordinate systems is limited to consideration of the rigid pelvis of living humans and its analogues.

PROPOSALS

Guideline 6

The use of guidelines 1 through 5 can be implemented more consistently by the adoption of a further guideline. In order to facilitate the selection of anatomical points and to name axes for coordinate systems derived from the anatomical points a standard anatomical position of the living human subject is proposed. Within this standard anatomical position points can be located, described, and used, more readily. Also the first, second, and third axes can be more consistently selected and named. The intent is to have the first, second, and third axes of anatomical coordinate systems of isolated segments align so far as possible to each other when the human standard anatomical position is established. It should be understood that no exact alignment is considered possible. Furthermore, many human analogues may not have an analogous position which includes all segments.

The recommended position for establishing the appropriate direction for the coordinate axes system should be the standard anatomical position illustrated in Fig. 1 (2). In this position the subject is erect with arms by the sides, palms forward. The following standard terminology is used:

(1) Anterior is toward the front

(2) Left lateral is toward the side shown

(3) Superior is toward the head

With the anatomy aligned as illustrated, three or more anatomical points should be selected and defined for establishing coordinate axes systems and the first axis should be closest to the anterior direction (+X), the second axis should be closest to the left lateral direction (+Y). The third axis will be closest to superior direction (+Z). This guideline is drafted primarily for the purpose of standardizing the selection of the first, second, and third axis directions called for in guideline 1 (1).

Pelvic Anatomical Coordinate System

The proposed definition of the pelvic anatomical coordinate system is almost identical to the example given in last year's report. It is defined by a triangle formed by the same relative points

on the right and left anterior superior illiac spines and the most superior anterior point of the symphysis pubis which is taken to be between the left and right public tubercles. The origin is located at the midpoint of the line connecting the anterior superior illiac spines. The first axis (+X) is normal to the plane of the triangle which is closest to the anterior direction recommended in guideline 6. The second axis (+Y) is to the left along the line connecting the anterior superior illiac spines. The third axis (+Z) is at right angles to the other two which is closest to the superior direction recommended in the guideline. This coordinate system with the first, second and third axes identified by +X, +Y, and +Z respectively is illustrated on the lateral and anterior-posterior x-ray views of a 3M® human x-ray phantom in Fig. 2 and 3. The projection of the +Y and +Z axis onto the x-ray is shown in Fig. 2. The projection of the +X and +Z axis is shown in Fig. 3. Although use of this coordinate system has not been reported for living human volunteer biodynamic experiments the selected reference points have been palpated to define pelvic orientation of volunteers (2). Also, this anatomical coordinate system has been successfully used with cadavers (3). Until this particular definition has been more extensively applied to living human subjects it should be considered only as a proposal. Furthermore, the ability to precisely localize the specified anatomical points is not known. The value of this coordinate system needs to be determined relative to other possible candidate coordinate systems. There are other candidate landmarks on the pelvis which could be considered in the construction of the pelvic coordinate axis system. Examples are the right and left posterior superior illiac spines, centers of the right and left acetabula, and a point located on the sacrum, for example the L5-S1 interface.

PROBLEMS

Localization of Anatomical Points

A conflict in the development of usable anatomically based coordinate systems is the ability to localize specified anatomical points in individual subjects by some measurement technique. There are two difficulties:

(a) Consistent identification of anatomical points by sight, palpation, x-ray, etc., from subject to subject and from living human to human analogues.

(b) Measurement of these points in three dimensions by some repeatable measurement technique.

It is anticipated that the effort to use anatomically based coordinate systems will stimulate efforts to better define and identify useful anatomical reference points in living humans. Also, techniques for measuring these points should undergo further development. This effort may result in other more usable anatomically based coordinate systems.

Anthropometry

Anthropometry must be considered in defining anatomical coordinate axes systems. The landmarks chosen to define the anatomical axis system must be reliably and reproducibly located. These landmarks have been defined traditionally for the purpose of establishing the initial limits of body shape and size. It is implicit in utilizing anatomical axes systems to describe dynamic properties of the body. Therefore, these landmarks should have known and well defined relationships to the body linkage systems and the anatomical segment intertial properties. Previous reports by several investigators have demonstrated that anthropometry can provide useful information but further work is essential before definitive solutions to many of these complex problems will be available (4, 5, 6).

Comparability of Human and Human Analogues

The effort of the last two years has been based on a presupposition that comparability of biomechanical data provided from diverse sources is a necessary requirement for the effective use of these data. However, the concept for comparability can have a much broader significance for biomechanics. One such extension is to include the effort to establish criteria of comparability between living human subjects and the human analogues. It is obvious that any analogue will be comparable to living humans in a limited number of ways. The adequacy of the comparability is dependent on the purposes of the comparison. The explicit statement of these purposes along with the variables and parameters from the items being compared must be clearly stated. Then criteria of adequate comparability can be established. This final step is a crucial end point of the biomechanical investigations seeking to develop analogues of the living humans.

CONCLUSION

The committee has proposed a sixth guideline which establishes a standard anatomical position for more consistently defining anatomical coordinate systems. Further, it has proposed a pelvic anatomical coordinate system. It has not proposed any recommendation concerning the possibility of preferred instrumentation coordinate systems or instrumentation performance. However, it continues to review proposals for such recommendations. A section listing specific fundamental problems with brief discussion has been added to the report to stimulate consideration and review of these issues by the biomechanical community of interest. Our purpose is to encourage investigation in these problem areas, to review suggested solutions, and present the solutions to these problems in subsequent reports as information becomes available.

ADMINISTRATIVE INFORMATION

The two annual reports prepared by this ad-hoc committee are the joint efforts of the committee membership based on their professional interests in response to the informal request of an International Ad Hoc Committee on "Human Subjects for Biomechanical Research". As such the conclusions and views expressed within these reports are those of the authors and do not express the views of their organizations. Request for the inclusion of these reports in any technical report or publication should be addressed to the chairman who will be responsible for seeking any required organizational clearance.

REFERENCES

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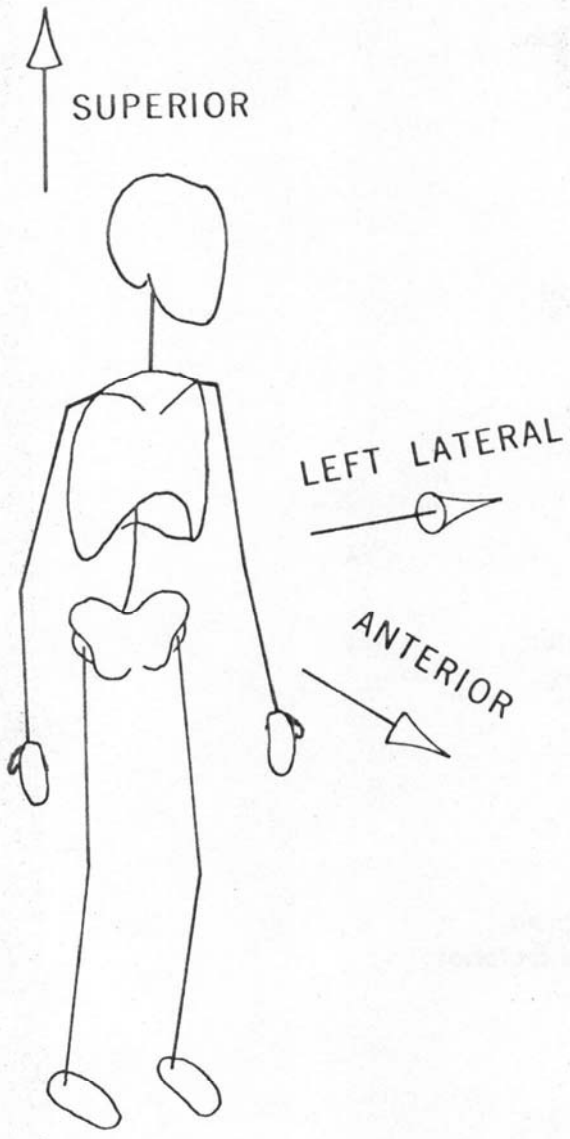

FIGURE 1 ILLUSTRATION OF THE ANTERIOR, LEFT LATERAL AND SUPERIOR DIRECTIONS BASED ON A STANDARD ANATOMICAL POSITION

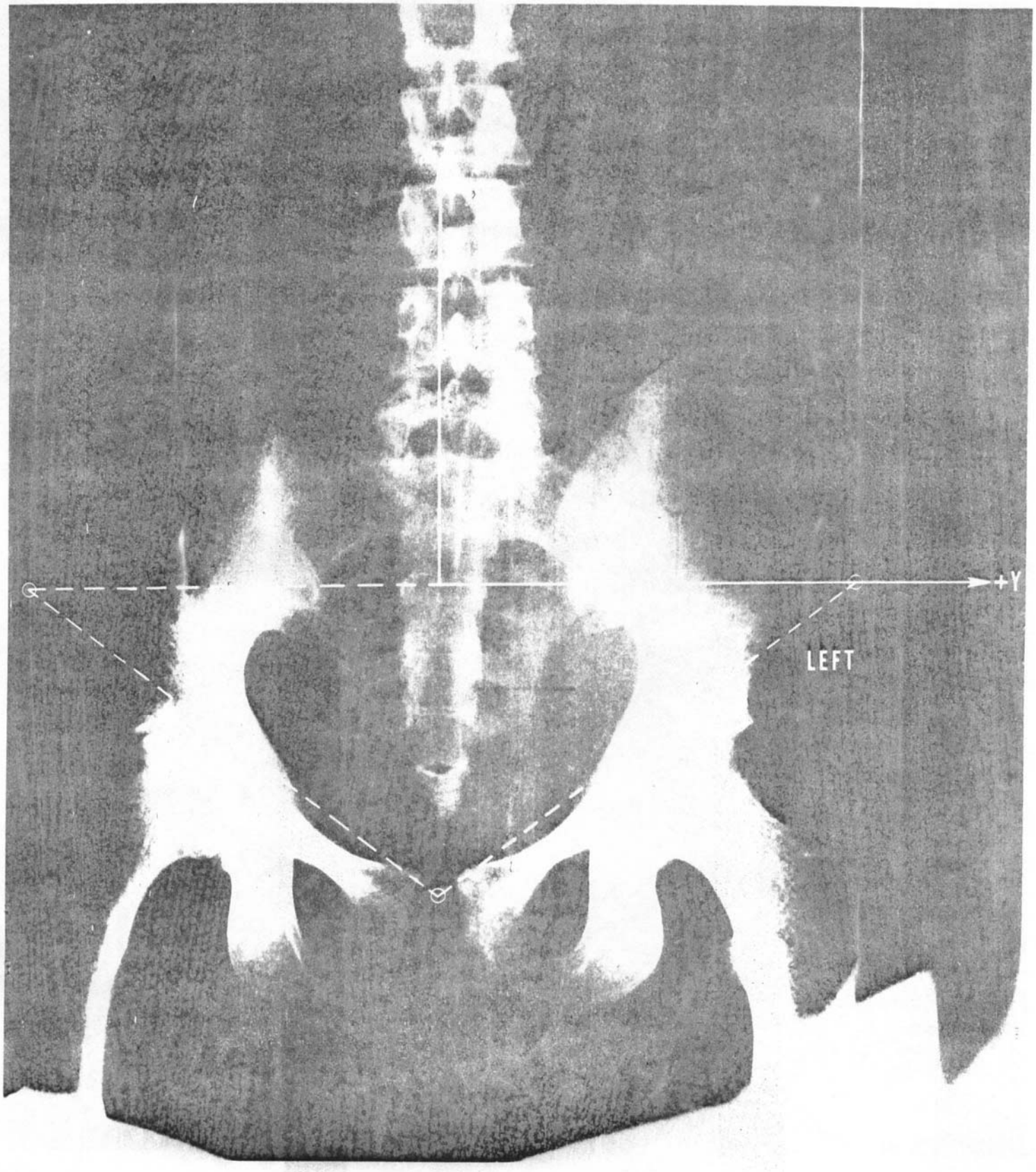

FIGURE 2 ILLUSTRATION OF +Y, +Z PROJECTION OF PELVIC ANATOMICAL COORDINATE SYSTEM

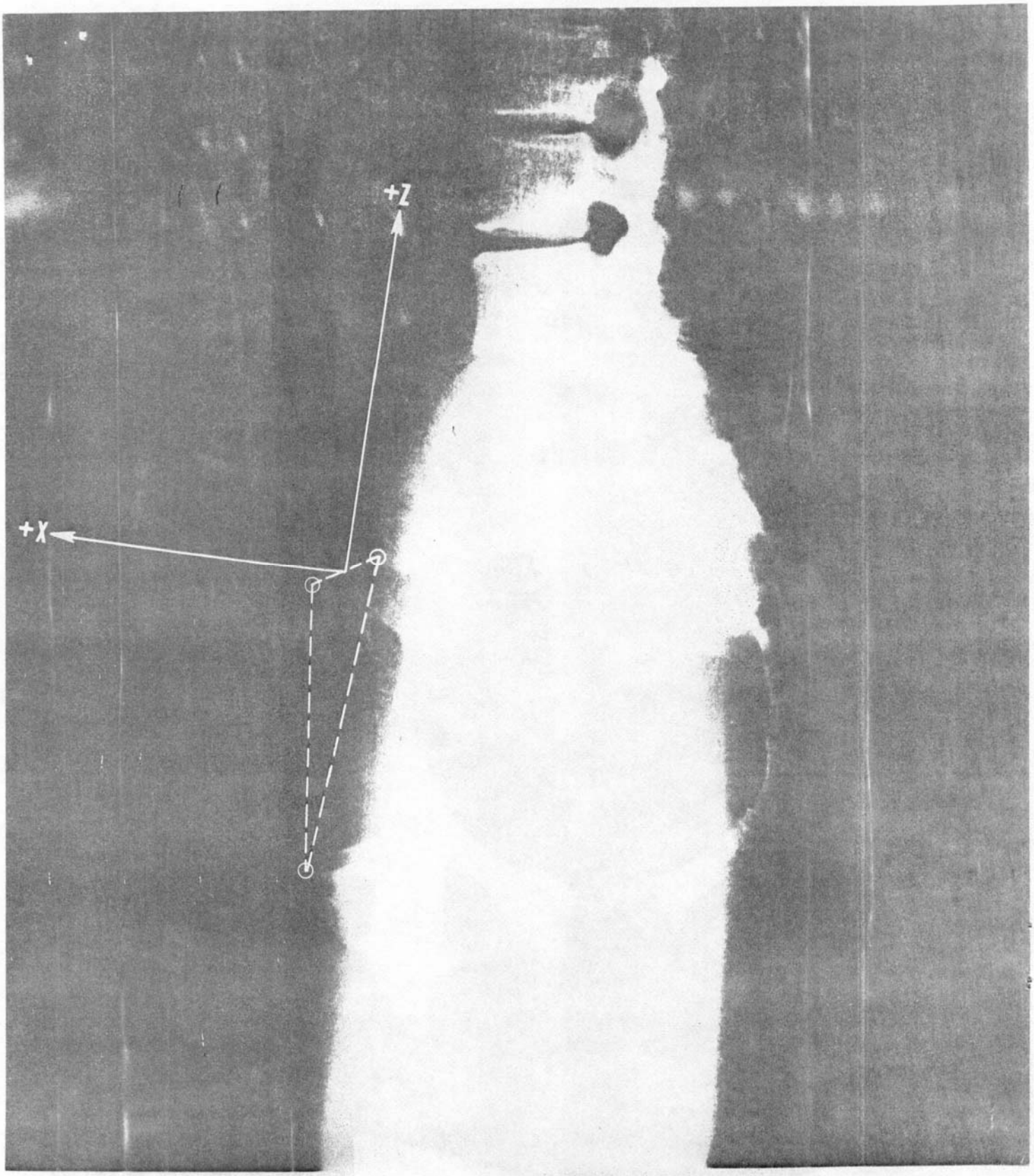

FIGURE 3 ILLUSTRATION OF +X, +Z PROJECTION OF PELVIC ANATOMICAL COORDINATE SYSTEM